GROVE KARL GILBERT.

The history of geology, like that of other sciences, affords occasional instances of an undue assumption of authority on the part of its eminent men, grown old in service: their earlier work had received so general an adoption that in later years they strove to impose less acceptable opinions upon their juniors, and came to regard dissent from their views as at once an error and an impropriety.

Never has there lived a geologist who could with better right than Gilbert have assumed an authoritative attitude among his fellows, for it has been well said of his work: "It is doubtful whether the product of any other geologist of our day will escape revision at the hands of future research to a degree equal to the writings of Grove Karl Gilbert"; yet never was there a geologist to whom an assumption of authority would have been more unnatural, or the wish to occupy a dictatorial position more remote. It was from no personal claim or urgency that his opinions found acceptance, but from the convincing logic with which they were set forth. It was his habit in presenting a conclusion to expose it as a ball might be held on his hand—not clutched as if to prevent its fall, not grasped as if to hurl it against an objector, but poised on the open palm, free to roll off if any breath of disturbing evidence should displace it; yet there it would rest in satisfied stability. Not he but the facts that he marshalled clamored for the adoption of the explanation that he had found for them.

Fortunately for the rest of us, Gilbert gave a clear account of this way of studying a field problem in an address on "The Inculcation of Scientific Method by Example," which he delivered as president of the Society of American Naturalists in 1885.[1] The problem chosen for treatment was the deformation of the Bonneville shorelines, part of a larger problem upon which he had been engaged for some years. The deformation of the shorelines is briefly set forth, and several alternative hypotheses proposed for its explanation are discussed at some length. Thus it is shown how observation is followed by induction, or the empirical grouping of discovered facts in accord with their conspicuously common characters; how hypothetical explanations are invented one after the other; how each explanation must

[1] See this JOURNAL, 22, 284-299, 1886.

be submitted to impartial tests, the tests being provided by comparing the "deduced consequents" of the hypotheses with the appropriate facts; and how the hypotheses which are found to be unsuccessful by the inability of their "consequents" to match the facts must be set aside as failures. There was truly nothing new in the mental processes of this analytical method, for its abstract equivalent is to be found in various treatises on logic; the merit of the address lay in the presentation of the logical processes as the successive steps of an actual and by no means elementary problem; and on this account it should still be studied by every young geologist, for in the thirty years since its publication no better illustration of scientific method has appeared.

But for our present purpose the address is of value as a revelation of its author's calm and unprejudiced way of thinking. The problems of the Great Basin and all other problems that Gilbert attacked were treated in the impartial manner that this address sets forth; and that fine quality of impartiality was not so generally to be found in geological discussions thirty or forty years ago as it is to-day. It may be well believed that Gilbert's influence, not only through this address but still more through his personal contact with the then rising generation of geologists, counted for much in bringing about the improving change.

It would be profitable, were it possible, to trace out the beginning and the development of the scientific habit of thought in Gilbert's mind. The beginning can hardly have been a paternal inheritance, nor can the development have been opened through paternal influence, for his father was an artist of moderate ability and limited means in Rochester, N. Y., where Gilbert was born on May 6, 1843. He finished his high school course there in 1858, and was graduated in 1862 from the University of Rochester, where he had taken the classical course. He is remembered by his companions, to whom he was known as "Karl," as a quiet and modest boy, with a gentle disposition, a lively sense of fun, pleasant manners, and a very even temper; he was a good student but indifferent to college honors.* The boy thus foreshadowed the man.

The thirty-five study units of his college course included eight of mathematics, six of Latin and seven of

* Prof. H. L. Fairchild of Rochester has kindly communicated these details regarding Gilbert's early years.

Greek; both the ancient languages were continued into his senior year. Rhetoric, logic and zoology each had two units; and nine other subjects, including French, German, and geology, but one each. The extended training in mathematics, for which young Gilbert had a natural capacity, served him well in certain geophysical researches of later years; perhaps his classical studies contributed to the clear style of his reports, as they seem also to have determined a tendency to the use of long words of Greek origin and occasionally to the invention of such words; but they did not prevent his later adoption of simplified spelling, which in his case as in so many others was evidently a matter of temperament, not of learning.

Gilbert's instructor in zoology and geology was Henry A. Ward, who came to be widely known for his extensive dealings in natural history specimens; the "Scientific Establishment" that he founded in Rochester was the source of many school and college collections: but unless by the rule of contraries it certainly cannot have been by the influence of this enthusiastic collector that Gilbert was led to say in the address, above quoted, that the important thing is to train scientists rather than to teach science, and that "the practical questions for the teacher are, whether it is possible by training to improve the guessing faculty, and if so, how is it to be done." It must have been Gilbert's own idea, not his professor's, that the content of a science is often presented so abundantly as to obstruct the communication of its essence, and that the teacher "will do better to contract the phenomenal and to enlarge the logical side of his subject, so as to dwell on the philosophy of the science rather than on its material."

The young graduate having no decided bent toward any profession or occupation, but having reached the pedagogically mature age of 19, taught school for a year at Jackson, Michigan, not as the beginning of a career, but, young-American like, as a means of paying off a debt which his college course had occasioned. Then returning to Rochester, he entered geology through being employed for five years as an assistant in Ward's Scientific Establishment above mentioned. His work there included the sorting and naming of countless specimens; many thousand labels in the Ward collection, afterwards acquired by the University of Rochester, are in Gilbert's

writing. He had also to do with the installation of exhibits in museums; it may have been in the course of journeys then undertaken that he learned something of the Appalachians, to which he refers in a most appreciative manner in his first western report.

The philosophy of geology could have been learned no better during these five laborious years of clerkship than during the preceding eight years of school and college study; yet a liking for the science seems to have grown up, for Gilbert next became a volunteer assistant on the Ohio Geological Survey, where he worked under Newberry from 1868 to 1870, receiving pay only for his field expenses. His drawings of fossil fishes are praised by his chief, but the best known result of this period of apprenticeship is his report on the surface geology of the Maumee "valley," a district of very faint relief lying southwest of Lake Erie. It is interesting now to note that Gilbert here attributed the higher levels of the lake, as attested by abandoned shorelines on the adjoining plains, to a former upwarping of the land in the lower St. Lawrence valley, an idea which he mentioned again five years later in his report on the Henry mountains; it was Newberry who, in a footnote, explained the higher lake levels by a retreating glacial barrier. When Gilbert was fifteen years older and greatly matured by his studies in the West, he returned to the region of the Great Lakes and recognizing the correctness of Newberry's opinion eventually brought out a masterful essay on the history of Niagara Falls, as will be further told below.

Gilbert's larger career began on the Wheeler Survey, which took him to Utah, Nevada and Arizona between 1871 and 1874. His first season of western work led him into problems that engaged his lifelong interest. Would that we had a narrative of his personal experiences and his mental progress in those new surroundings! The several chapters in his reports cover a large range of subjects:—stratigraphy, volcanic phenomena, plateaus and canyons, glacial and lacustrine records, and the mountain ranges of the Great Basin. Powell's and Dutton's more extended descriptions of the plateau province have distracted attention from the large contributions that Gilbert made to its elucidation. On the other hand the Basin ranges and the Lake Bonneville came to be regarded as peculiarly Gilbert's problems.

The theoretical discussion of the Basin ranges, for the

origin of which Gilbert proposed an altogether new interpretation, is regrettably brief; but it is fortunately recorded that the Great Basin was entered with the expectation of finding the hard rocks standing in relief, and the weak rocks worn down in valleys and lowlands, as he knew them to be in the Appalachians; and on discovering that the Basin ranges "occupy loci of upheaval and are not mere residua of denudation"—to quote his classico-mathematical phrase—he was greatly surprised. "The valleys of the system [*i. e.* the broad intermont depressions] are not valleys of erosion but mere intervals between lines of maximum uplift. Within the ranges there are indeed eroded valleys, and the details of relief show the inequalities of erosion due to unequal resistance; but there is not on a grand scale that close dependence of form on durability that must maintain where the great features of the country are carved by denuding agents." The ridges were found to be more persistent than the structures; one was instanced across which an anticline runs obliquely. The excavation of the broad intermediate depressions by erosion, while the ranges remained in bold relief, was seen to be impossible. The valleys were, therefore, explained as belts of relative depression, and the ranges as belts of uplift. Thus began a long discussion which is not yet closed to the satisfaction of all concerned. The geologists of the Fortieth Parallel Survey had, before Gilbert had entered the field, interpreted the Basin ranges as prevailingly of anticlinal structure between broad and deep synclinal valleys; but Gilbert's theory was afterward adopted to the extent of adding vertical displacements by faults to the earlier deformation by folding, yet without going so far as to give to the faults the dominant value in producing the existing relief that Gilbert had attributed to them.

Unfortunately the leading chapter in Gilbert's report concerning the Basin ranges occupied only twenty-two pages, and of these only a few at its end were devoted to theoretical discussion. This was by no means sufficient space for a clear exposition of his novel views; indeed it is not possible to ascertain from his text alone how fully he had worked out the "consequents" of the fault-block theory of mountain formation. The important physiographic principle that is involved in demonstrating the presence of a great fault by the truncation of diverse rock structures in simple alignment along the mountain

base could not be easily apprehended from the few lines that Gilbert gave to it; indeed some of those geologists who, a quarter of a century later, opposed Gilbert's view do not seem even then to have appreciated this essential element of his discussion.

The regrettable brevity of the Basin-range chapter is perhaps to be explained by the dissatisfaction of its author with the military ordering of the Wheeler Survey. The young geologist had been permitted by Newberry to publish an abstract of his Maumee valley studies in the *American Journal of Science* two years before it came out in a volume of the Ohio Survey; but on asking a similar permission regarding some of his western work it was refused by General Humphreys, chief of engineers, under whose direction Lieutenant Wheeler's Survey was conducted. Whether this was also the cause of Gilbert's leaving the Wheeler and joining the Powell Survey does not appear; but on Nov. 27, 1874, after the transfer had been made, he wrote from his home in Rochester to Powell:—"I feel little ambition to write anything for publication with the uncertainty that would hang about the date of its appearance. . . . I am getting a little anxious to be at work—partly because it has come to be more natural than play, and partly because I ought to be earning something. So I am going to Washington in a few days, with the intention—if you have not changed your mind—to begin work with you at once." Thus he entered upon a period of the most loyal and substantial service under his new chief.

In the course of his continued western field work, Gilbert spent a week in the summer of 1875 in the Henry mountains of southern Utah, and found them so interesting that, probably on his own request, he was sent there for two months of 1876; as a result we have one of the most notable of all his reports. Its greater part treats the type of intrusive structures, previously recognized in a general way by earlier geological visitors, to which he gave the name of "laccolites." This text clearly illustrated his power to deal convincingly, if he took the time, with a new structural problem, involving many local details. The report described an area of about 1000 square miles of desert, mountainous country, as surveyed on his two visits. Gilbert recognized that the time was short for so great a task, for he wrote:—"A few comprehensive views from mountain tops gave

the general distribution of the formations, and the remainder of the time was spent in the examination of the localities which best displayed the peculiar features of the structure. So thorough was the display and so satisfactory the examination, that in preparing my report I have felt less than ever before the desire to re-visit the field and prove my conclusions by more extended observations." The method of presentation, beginning with covered laccoliths and ending with denuded and partly undermined laccoliths, is so persuasive of the announced conclusions that the need of revising them has seldom been suggested.

The closing chapter of the Henry Mountains report, an essay on "Land Sculpture," has in this country at least been of greater service though not of greater interest than the four which precede it. The contents of the famous essay cannot be analyzed here; but two peculiarities of its treatment may be mentioned. One is the lack of reference to similar work by foreign students, for though several Americans are named, Hopkins is the only European mentioned; and this was naturally enough unsatisfactory to geologists and geographers abroad; but the fact of the case seems to be that Gilbert, like most of his early colleagues, had never been trained in the time-consuming but dutiful labor of looking up the "literature" of a subject, and that he was so absorbed in his western problems and so overwhelmed with the abundance of new material to be described, that he had no time to look across the ocean in search of precedents for his opinions. Another peculiarity, harder to account for, is the complete absence of Powell's term, baselevel, which had been published in 1875; indeed even the fundamental principle embodied in the term is hardly touched upon, except in so far as it is tacitly implied in the discussion of "declivity."

The study of Lake Bonneville, which Gilbert began under Wheeler and continued under Powell, was carried farther in the field and published in more elaborate form than any other subject that he undertook. It became his own problem and is so still, although a new interpretation of the shoreline chronology has been proposed by recent observers. The Bonneville monograph established a high standard with respect to which the records of vanished lakes in all arid continental basins must be treated. Its first sequel was Russell's monograph on

Lake Lahontan, but as yet it has had no other. The chapter on the "Topographic features of lake shores," originally published as one of the brilliant essays with which Powell enriched his annual reports as director of the national Geological Survey, and reissued as the cornerstone of the final monograph, deserves special mention because it gave so great an impetus to rational physiography. It held good for sea shores as well as for lake shores, and every one of its uncounted readers must have discovered in it a fuller treatment of such shoreline features as he had somewhere seen than he had found in any text-book, and far better than he had prepared himself.

The establishment of the United States Geological Survey in 1879 caused a fateful turn in Gilbert's life. Its first effect was to give him unrivalled opportunity for the detailed study and—after delay owing to the intrusion of other duties—the handsome publication of the Bonneville problem, as above noted; but its longer lasting effect was to withdraw him from the western field, where his work had been so fruitful and where he would have so gladly gone on working; he was not only placed for some years (1884-1888) in charge of Appalachian geology, but was for a time (1889-1892) burdened with the executive duties of "chief geologist," a position for which he had neither especial fondness nor marked fitness. Yet when the director of the Survey called him to these duties, he put aside a cherished plan of continuing his work in the Great Basin—especially a research into the strength of the earth's crust as indicated by the deformation of the Bonneville shorelines—and, with self-denying devotion, took up the tasks assigned to him: but he said, in his address on the " Inculcation of Scientific Method":—"It is hardly necessary for me to assure you that my personal regret in abandoning this research at its present stage is very great."

Gilbert never reaped any significant public advantage from his supervision of the Appalachian division, for with characteristic generosity he gave such results as his limited opportunity for field work afforded to his assistants and his friends, as contributions to their more detailed investigations. As chief geologist he was in a manner embarrassed by his habit of deliberation, for Survey problems usually called for prompt decision. It was, therefore, fortunate that, when Powell withdrew

from the Survey in 1894, it contained another man of conspicuous administrative capacity, well trained to carry on and to carry farther its great organization. The scientific world expected the new director to be Gilbert, but he himself had no such ambition and was well content to return in his later years to scientific research.

The ten years of Gilbert's mature life that were largely spent in the West won for him a deservedly high place in geological science. The following twelve years spent largely in Washington gave him high rank among scientific men. The chief lesson of his western work comes rather from the transparent reasonableness of his methods of investigation and—excepting the too-short chapter on the Basin ranges—from the delightful clearness of his style of presentation, than from the results that he reached, important as they were. The chief lesson of his life in Washington has not been fully recognized by his colleagues; it was a lesson not in science but in loyalty, the great lesson of self-sacrificing service. He gave up his own preference for investigation and turned largely to administrative duties, as they were seen by the chief under whom he had enlisted. Yet even thus, his effect on geological science, although for the most part anonymous, was very great. His advice was highly valued in the Survey and outside of it. His opinion usually carried his associates far toward a conclusion. On terminology, correlation of formations, map coloring, form of folios, and other technical matters he submitted serious, even elaborate discussions, some of which were published as a means of bringing Survey problems more clearly to the attention of American geologists.

Happily his administrative duties included close relations with many younger men, and this was as enjoyable to Gilbert as it was profitable to his juniors, for his nature was kindly, patient and sympathetic. Those who had to report their work to him carried away inspiration from every contact. The encouragement of his approval was a spur to new effort. To one of his subordinates with whom he was reviewing the proposed solution of a problem in the field, he said rather brusquely after a reflective pause at the end of the day:—"How did you find it out?" This brief remark was then taken and is still treasured as the highest reward of a long study; for if, after hearing the solution of a problem, that keen investigator cared to ask how it had been found out. . .!

Gilbert's helpful influence extended far beyond the Survey office in Washington. When articles and reviews appealed to him, he had the pleasant way of writing a note of appreciation to their authors; and these spontaneous expressions of approval from so competent a critic won for him the warm regard of many younger men who had little or no personal acquaintance with him. Indeed two generations of American geologists entertained toward this master of their science a sentiment that approached affection more closely than is common among men. It was about as much as an expression of personal regard as of scientific esteem that he was chosen president of nearly every learned society of which he was a member. His bearing in the chair had a simple dignity that was very acceptable to his constituencies. He was a welcome speaker at all scientific gatherings where his fine presence went well with his exceptional clearness of exposition.

In personal relations he was frank and outspoken, free from all formalities, a delightful companion indoors and out, with a lively sense of humor and a merry laugh. Indeed he was often by no means so serious as he looked. On meeting an over-assiduous correspondent he said:—"I received a long circular letter from you lately, and I've put it away in a safe place." His whispered comment on a speaker who had made an inconclusive reply in a discussion was in the western phrase:—"You can't prove it by him." A friend once inquired whether a visiting European geographer of distinction, whom Gilbert had guided on an excursion, was quick in responding to field evidence. "Hair trigger," was the concise reply. Not long afterwards when the inquirer repeated the characterization to its beneficiary—alas for the break of relations with him in these troubled years!—it brought forth the puzzled exclamation—"Vat is 'hair trigger'?"—but the phrase gave much satisfaction when explained.

After Gilbert's relief from the position of chief geologist of the National Survey, he continued for a time in charge of correlation problems, and was then (1893-96) assigned to study certain areas of the great plains, where he prepared two geologic folios. In later years he held various roving commissions. Among these were the study of the Great Lakes region, which he had already taken up in 1885 as if for vacation exercise in the field, and in which he had then at once made the fruitful dis-

covery that the ancient shorelines, which he had earlier known in the Maumee valley, southwest of Lake Erie, ascended to the northeast. This compelled him to give up the idea he had originally entertained, that the lakes had been raised by an upheaval of the land in the St. Lawrence district, and to adopt Newberry's view that the high-level lakes were enclosed by a retreating glacial barrier. Intermittent attention to this problem resulted in 1896 in a "History of the Niagara River," a most luminous generalization, published in the Sixth Report of the Commissioners for the [N. Y.] State Reservation at Niagara. More formal study, when the Great Lakes came to be an official assignment (1896-97), produced a report on "Earth Movements in the Great Lakes Region," published in the 18th Annual Report of the Director of the Survey.

In 1899, Gilbert visited Alaska as a member of the Harriman expedition and there recognized the convincing evidence of intense glacial erosion that is given by the much greater depths of the main fiord troughs than of their lateral tributaries, for which it was he who suggested the name of "hanging valleys." His observations are reported in a fine volume on Alaskan Glaciers, where he brought forth the noteworthy idea that glaciers which invade the sea rest so heavily on their trough floor that no sea water can enter beneath to buoy them up; and that they therefore continue to press upon and to erode their floor with their whole weight, even if six-sevenths or more of their thickness is submerged. The San Francisco earthquake was later the subject of study, and following this came his last formal work, an examination of the conditions under which gravels have been spread forth from hydraulic gold washings in California; this resulted in Professional Paper No. 86 of the Survey, entitled "The Transportation of Débris by Streams." During the progress of these two studies, Gilbert was frequently at Berkeley, where he was a welcome guest of the hospitable Faculty Club of the University of California, as he was also of the enterprising "Sierra Club" of San Francisco during its summer excursions in the mountains.

The breadth of Gilbert's interests is shown by the many topics on which he wrote besides those already enumerated. They include, among others, barometric hypsometry, the percentage of success and error in weather

prediction—but the misprints in this article in the American Meteorological Journal were so numerous that its author had no satisfaction in it—ripple marks, joints, the sufficiency of terrestrial rotation for the deflection of streams, the origin of the "craters" of the moon, which he suggested might be the result of meteoric impacts, an idea that he later applied also to Coon Butte in Arizona in an address on the "Origin of Hypotheses" (1896); the systematic asymmetry of mountain crests in the Sierra Nevada as a result of glacial erosion, and the convexity of hill tops as a result of soil creep—a small problem that he had left unsolved nearly forty years earlier in the chapter on Land Sculpture in the Henry Mountains report. He also collaborated in producing an elementary text-book on Physical Geography.

In all these studies, his keen insight tended, as has been well said, "to bring into declared form the basal principles that underlie the phenomena in hand." He was thus led to understand earlier than many of his colleagues that the Adirondacks were not, as had long been thought and taught, a rising but a sinking land mass when the Potsdam sandstones were laid unconformably on their flanks; and that the fresh-water Tertiaries of the Rocky mountain region had not been deposited in great lake basins, a long prevalent view that he had himself adopted in his early western work, but that they were largely deposited by aggrading streams. It was, therefore, in view of the breadth as well as the depth of his researches that he was awarded the Wollaston medal by the Geological Society of London in 1897, and the Walker Grand Prize—a thousand dollars—by the Boston Society of Natural History in 1908.

It remains to recur briefly to Gilbert's return to the Great Basin in 1901, with the object of revising the field of his early work on the origin of the Basin ranges; for a new discussion of the old problem had been awakened by a junior geologist who expressed strong dissent from the fault-block theory. A season of successful field work supplied the veteran observer with more detailed evidence than had been before available for the correctness of his theory—which, it may be noted, had received independent confirmation from Russell's work in Nevada and Oregon some years before, and was about to gain still further support from studies by Campbell in Death valley and by Louderback on the Humboldt ranges; but most

unhappily the maps on which much of Gilbert's new observations had been recorded were destroyed by sad mischance in the following winter, and under this discouragement further field work was suspended. The main results of the study were, however, presented at a meeting of the Geological Society of America in Washington in the winter of 1903-04, in a manner that was convincing to many if not to all hearers; but the printed record in the Society's Bulletin was compressed into a few lines, which merely state that the evidence of great faulting lies in the occurrence of extensive shear zones, in triangular facets at ridge ends, and in the even linear bases of the ranges. Thus, in spite of the clear conception of the problem indicated by Gilbert's oral presentation, the printed record remains deficient.

The loss of the map was probably the larger cause of this brevity, but a contributing cause was failing health, as a result of which it had become increasingly difficult for this master of exposition to apply himself to writing. For the same reason he later had to forego attendance at scientific meetings and participation in discussions. Thus at the very time when all his associates would have most delighted to welcome and to honor him, they saw the least of him; yet those who were still favored to meet him found, if not the same strength, the same noble geniality that they had learned before to love admiringly. Indeed, these years of withdrawal were marked by a serenity of mind that made his face more than ever benign. All his fine qualities seemed to shine forth undimmed:—openness of mind, breadth of sympathy, calmness of judgment, mental honesty, sincere humility in the contemplation of mysteries unsolved. One of Gilbert's last projects, after the completion of his two California tasks, was to visit for the third time the scene of his early work and to take up yet again the origin of the Basin ranges, but health failed him. In the spring of the present year many of his friends, acting on a suggestion from the office of the Survey where he had so faithfully labored, wrote letters of congratulation that were to be presented to him on his seventy-fifth birthday; but these messages of affectionate regard failed to reach him by the narrow interval of five days. He died at Jackson, Michigan, on May 1.

WILLIAM M. DAVIS.